Sustainability potential of suburban gardens: review and new directions

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Abstract

Gardens, as important elements of Australian suburban residential environments, could have significant sustainability potential similar to that of dwellings. Research to identify the cumulative (social, cultural, environmental and ecological) sustainability values of suburban domestic gardens has been very limited. Australian suburbs are likely to retain their typical characteristics for a considerable period of time as their rapid intensification is not likely. Therefore, it is immensely important to understand the role and performance of the suburban garden in this discourse. This article reviews the sustainability potential of domestic gardens and their links to suburban forms, sustainable design, social processes, and environmental and ecological functions. It explores whether gardens could be re-imagined as energy and water sources rather than sinks. This research presents a holistic conceptual sustainability model for gardens and establishes that suburban gardens can provide multiple sustainability benefits.

Keywords

suburban, review, directions, gardens, sustainability, potential

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Sustainability potential of suburban gardens: review and new directions

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Gardens, as important elements of Australian suburban residential environments, could have significant sustainability potential similar to that of dwellings. Research to identify the cumulative (social, cultural, environmental and ecological) sustainability values of suburban domestic gardens has been very limited. Australian suburbs are likely to retain their typical characteristics for a considerable period of time as their rapid intensification is not likely. Therefore, it is immensely important to understand the role and performance of the suburban garden in this discourse. This article reviews the sustainability potential of domestic gardens and their links to suburban forms, sustainable design, social processes, and environmental and ecological functions. It explores whether gardens could be re-imagined as energy and water sources rather than sinks. This research presents a holistic conceptual sustainability model for gardens and establishes that suburban gardens can provide multiple sustainability benefits.

Keywords: suburban gardens, sustainability potential, environmental performance, sustainable gardens, urban form, cities

Suburbs manifest unique cultural identities and values for the Australian way of life (Gleeson 2006). According to 2006 census data, 68 per cent of the total Australian population now lives in the major cities and their suburbs (ABS 2008). The spatial geographies of Australian suburbs have been continually shaped over time by changing socio-cultural and economic processes, political power plays, migration, household diversity, home-ownership and housing-market trends, the potential for utility and public transportation infrastructure, impacts of public policies, and people's passion for suburban lifestyles (Forster 2004; Gleeson 2006).

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Gardens are important elements of Australian residential suburbs. In reality, gardens can increase population spread across the urban-rural continuum for preferred life-style choices (Gordon & Richardson 2001; Kaplan & Austin 2004). A significant percentage of households wish to live in 'a single-family home with a private yard' (Gordon & Richardson 2001, p. 140; Kaplan & Austin 2004, p. 235). A research study on 18 residential communities living in new commuter-based subdivisions in Hamburg Township, south-eastern Michigan in the USA, has established 'the garden' as one of seven distinct kinds of natural areas that attract people to the countryside (Kaplan & Austin 2004, p. 235).

Cumulative areas of suburban gardens as urban green space constitute the largest single urban land-use type and a substantial proportion of a human settlement (Randall et al. 2003; Gaston et al. 2005). Domestic gardens with a mean area of 151 m^2 cover approximately 33 per cent of the urban area of the city of Sheffield in the UK (Gaston et al. 2005). Vegetated private garden areas were mapped as covering 46 per cent of all residential areas or 36 per cent of the total Dunedin urban area in New Zealand, with a ratio of garden to houses of 1:089 (Mathieu et al. 2007).

As the intensification of existing suburbs is not likely within a short timeframe, the suburbs are likely to retain their typical characteristics over a considerable time period. This raises several important questions in relation to the cumulative social, cultural, environmental and ecological sustainability values and contribution of domestic gardens. What will be the time-line for sustainability retrofitting of houses and gardens in the overall existing suburban fabric? Will it be possible for communities to adopt lifestyles that utilise the sustainability potential of suburban domestic gardens before significant environmental degradation occurs? To address these questions, it is immensely important to understand the role and performance of the suburban garden in contributing to urban sustainability.

As the association between the suburban garden and sustainability has seldom been explored in existing research, it would be beneficial to review the range of social and environmental variables and processes of gardens that influence the various forms of sustainability potential. This article aims to synthesise research on domestic gardens in suburban landscapes to identify the potential for, and barriers to, urban sustainability values, and the links between gardens, suburban forms and social, environmental and ecological functions. It offers an alternative perspective that seeks to comprehend whether Australian suburbs could be re-imagined as energy and water sources rather than sinks.

The article also aims to develop an integrated conceptual sustainability model for suburban domestic gardens. Specifically, this research focuses on domestic gardens in low and medium-density residential developments and therefore, does not include discussion of community gardens. Domestic gardens have different characteristics in terms of their ownership, mode of operation, land-cover patterns, sustainability potential and social qualities when compared to the attributes of community gardens. In this article, a domestic garden is defined as a place where social processes, design expressions, and environmental and ecological sustainability interact holistically.

Suburban forms and domestic gardens

Two patterns: 'compact' and 'sprawl'

Two main settlement forms identified in the urban sustainability research from sustainability performance perspectives are 'compact' and 'sprawl' (Newman & Kenworthy 1989; Jenks et al. 1996). Substantial debate exists between advocates of suburbs (i.e. low density urban development) and proponents of urban intensification (i.e. high density development) (Newman & Kenworthy 1989; Stretton 1989; Troy 1996; Breheny 1997; Gordon & Richardson 1997; Troy et al. 2005).

Urban consolidation is considered a preferred solution for its ability to reduce transport emissions (Newman & Kenworthy 1999); to protect regional water quality and ecologically-sensitive land areas (EPA 2006); and to foster better social interactions (English Partnerships & The Housing Corporation 2000). Urban consolidation is widely adopted as 'today's visionary solution' (Guy & Marvin 1999) and has been extensively incorporated in strategic plans and policies in Australia.

However, the success of compact environments as sustainable urban forms will be determined by people's satisfaction with their quality of life (Jenks & Dempsey 2005). It has been argued that achieving higher environmental self-sufficiency through on-site essential resource inputs and sustainable practices is more feasible in lower density settlements (Moriarty 2002). The Sydney study by Troy et al. (2005) demonstrated that actual per capita water consumption and garden water usage values (affected by specific rainfall patterns) of houses and high density apartments are only marginally different (Troy et al. 2005).

Potential to accommodate future sustainable technologies on-site varies with the associated spatial characteristics of different residential urban forms (Ghosh et al. 2007). The implications of residential densities (i.e. the number of people or dwellings per unit area) in cities and suburbs from a performance perspective are considered imperative to sustainable development but significant difficulties and controversies exist in measuring densities in the absence of a standardised methodology (Jenks & Dempsey 2005). However, the potential of low and medium-density residential developments with larger gardens as better places for producing on-site local food, promoting efficient water consumption, and enhancing biodiversity and ecological functions has been well established through many research studies (Moriarty 2002; Pauleit et al. 2005; Daniels & Kirkpatrick 2006; Gaynor 2006; Moroney & Jones 2006; Loram et al. 2008).

Land-use and land-cover characteristics of gardens

Domestic or private gardens in residential land-use zones (Smith et al. 2005) could be classified under an open or green space land-use type, but land-cover patterns for the same could be of multiple types. Land-cover composition depends on the: position along a rural-urban gradient; parcel size; land-use mix (i.e. single family/multi-family/residential-commercial); year built (Alberti & Marzluff 2004); and immediate influence zone (Smith et al. 2006). Urban morphogenesis or incremental changes in houses and gardens happen throughout their life-spans (Whitehand et al. 1999).

Garden size has a significant influence on garden composition. The Biodiversity in Urban Gardens in Sheffield (BUGS) project in five cities (Belfast, Cardiff, Edinburgh, Leicester and Oxford) in the UK investigated relationships between the ecological functions of urban gardens, housing characteristics, and the nature of surrounding landscapes (Loram et al. 2008). Larger gardens were more likely to contain particular features, such as tall trees, mature shrubs, and areas of un-mown grass, uncultivated land, vegetable patches, ponds, and composting sites (Loram et al. 2008).

Spatial imagery and aerial photographs have been widely used in measuring land-cover composition and changes in gardens at various spatial scales (Mathieu et al. 2007; Loram et al. 2008). Mathieu et al. (2007), using an

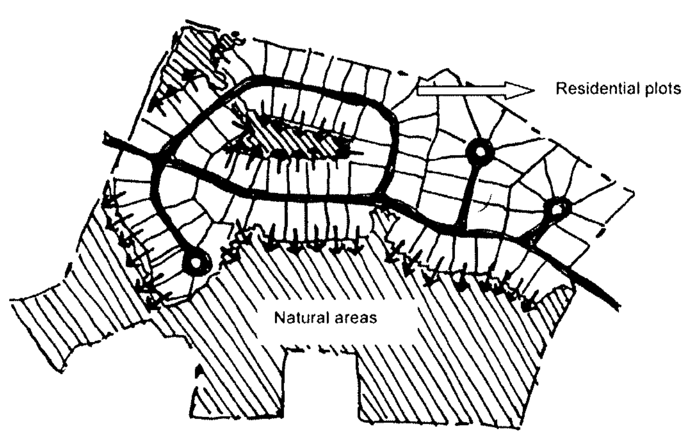

Figure 1 **Conservation subdivision design: Garnet Oaks, Pennsylvania, USA** (Drawing by Sumita Ghosh, Information sources: Natural Lands Trust 2001; Regional Planning Commission 2010)

object-oriented methodology, mapped the extent, distribution and density of private gardens as an ecological resource in Dunedin, New Zealand, and formulated a typology with three garden types: Garden 1 (dense trees); Garden 2 (open trees/shrubs) and Garden 3 (open grass) (Mathieu et al. 2007, p. 184). In contrast, the BUGS project surveyed 267 rear gardens and identified three main land-cover types: patios (93.3 per cent), cultivated borders (86.9 per cent), and mown grass (77.5 per cent) (Loram et al. 2008). In addition, a study comparing two Australian suburbs, given the pseudonyms 'traditional' (i.e. conventional, suburban residential neighbourhood) and 'modern' (i.e. emerging, suburban contemporary residential development), established that there were significant spatial land-cover variations between front, rear and side garden spaces (Ghosh & Head 2009).

Using Geographic Information Systems (GIS) and aerial photographs, Ghosh (2004) conducted objective estimates of various land-cover distributions on a household basis in five residential case studies in Auckland, New Zealand (Ghosh 2004; Ghosh et al. 2007). Land-cover compositions in gardens (e.g. tree canopy cover, paved/unpaved surfaces, building roof area, lawn etc) represent particular environmental qualities (e.g. carbon sequestration, storm water run-off, rainwater collection, local food production) that could be subsequently linked with sustainability performance measures. These characteristics are very important for assessment of the potential environmental and ecological sustainability performance of any development.

Sustainable design, technologies and applications

New approaches to designing gardens as important elements of sustainable rural and suburban spatial fabrics have been applied to various developments in recent years. The *conservation subdivision approach* fits very well with the vision of a sustainable suburbia for its abilities to provide better urban growth management, greater community satisfaction, enhanced marketability, and environmentally constructive ecosystem restoration potential through connection to natural areas (e.g. Garnet Oaks, Delaware County, Pennsylvania; Figure 1) in rural and suburban residential areas (Arendt 2004; Austin 2004). A study by Smith et al. (2006) in the UK highlighted the significance of integrated planning while investigating multiple influences within a circular catchment area of 10 000 m^2 (1 ha) around each garden. Suburban gardens could be interconnected with broader regional- and national-scale environments, including catchments, green space networks and landscapes (Smith et al. 2006), which could promote environmentally constructive activities and ecosystem restoration through revival of local ecosystems.

Application of *water sensitive urban design and development* (WSUD) principles allows sustainable solutions through appropriate storm-water management by improving quality; reducing run-off quantity; removing pollutants; and minimising infrastructure costs and potable water demand (Melbourne Water 2010). Porous paving use could increase infiltration of storm-water from zero to 80 per cent (Stone 2004). Conventional, suburban residential development with a larger garden could offer more space for rainwater tank installation than a contemporary development with a large house and smaller garden space, although the latter could collect more roof rainwater (Ghosh & Head 2009).

The potential roles of *renewable energy or micro-power generation* (e.g. photovoltaic (PV) panels, solar hot water, wind, and combined heat and power (CHP)) are clearly established in pioneering carbon-neutral and sustainable residential developments. Pergolas and ancillary structures, such as garages and sheds in garden spaces, offer useful roof surface areas for installing solar PV panels and hot water systems. A study by Ghosh and Vale (2006) established that a significant amount of solar-efficient building roof area could be lost if building

Table 1 **Sustainability design and garden spaces**

International medium- and low-density developments	
Name, type and descriptions	Garden/open spaces, energy and water
Village homes, UC Davis, California, USA (Francis 2002) Low density; Site area: 24 hectares; 242 single and multi-family residences; Density: 10 dwellings/ hectare	Informal and naturalistic community and home-garden spaces to promote water conservation, local food production, habitat protection and solar generation; landscaping is either edible or native
Earthsong Eco-neighbourhood, Waitakere City, West Auckland, New Zealand (Earthsong Eco-Neighbourhood 2010) Medium-density in New Zealand context; Site area: 1.62 hectares/4 acres; 32 homes; Density: 20 dwellings/ hectare	Organic orchard, an area of native bush, private domestic and community gardens for local food production and edible landscaping; solar hot water panels and passive solar design of houses; household energy use is 58 per cent less than usual; all water from rooves and car parks flows into rainwater tanks ; grass swales, bio-retention ponds, permeable paving, wetlands; 41 per cent reduction in water use; 45 per cent rainwater used
Hockerton Housing Project, Nottinghamshire, England (HHP 2010) Low density; Site area: 10 hectares; Contains 5 earth-sheltered houses; Density: 2 dwellings/ hectare	Orchard and apiary; household private and community garden for recreation and organic food growing; organic waste composting for use as fertiliser; 3600 m² man-made lake for fish farming, recreation and biodiversity protection; crop cultivation and rearing of small animals; passive solar heating and photovoltaic modules ; wind-power generation from 2 turbines of 5 kW; reed bed system to clean up on-site septic tanks system outflow; water collection from fields, roads, rear areas of houses via swales, underground tank to reservoir (150 m³) for non-drinking uses; water retention in ponds and lake; large open spaces used for water catchments; potable water collection from rooves
Australian medium and low density developments	
Name, type and descriptions	Garden/open spaces, energy and water
Pinakarri, Hamilton Hill, Fremantle, Perth (Pinakarri Community Inc. 2008) Medium-density Australian context; Site area: 0.03 hectare; Nine buildings; Density: 45 dwellings/ hectare including a common house	Shared open space and permaculture community and personal food gardens for growing fruit, vegetables and herbs; open spaces used for composting, worm farming, recycling, and as areas for children's play and social interaction; sustainable life-styles Passive solar design; each house orientation along east - west axis; minimal space heating; solar hot water systems; rainwater tanks for water conservation
Aurora Housing Development, Epping North, Melbourne (VicUrban 2010; McLean 2010) Low- to medium-density development; 8000 residential homes; Density: 10-30 dwellings/ hectare	630 hectare (20 per cent of the total site) land as parkland and conservation areas; gas-boosted solar hot water; rain gardens and rainwater tanks at the subdivision scale; bio-retention trenches and swales at the streetscape scale; on-site wastewater treatment plant; estimated reduction in water discharge by 40 per cent from site, potable water demand reduction 70 per cent
Regent Gardens, Northfield, South Australia (Downton & Fulton 2001) Low- to medium-density development Site area: 77 ha; 1250 homes Average Density: 16 dwellings/ hectare	10.6 ha open space area; on-site storm-water harvesting and re-use; innovative aquifer storage and recharge techniques; water detention in swales and wetlands; reed beds reduce pollutant loads; at peak salinity levels 550g/Litre less than ground-water

roof forms are inappropriately designed. Other than on rooves, wind turbines mounted on poles could be located in garden spaces. Some of the low and medium-density international best practice examples are presented in Table 1.

Figure 2 presents different types of garden spaces in a medium-density, sustainably designed, co-housing community: Earthsong Eco-Neighbourhood in Waitakere City, New Zealand.

Sustainability potential of suburban home gardens

Environmental and ecological sustainability significance of garden features

Gardens are places where a multitude of conservation and consumption practices and knowledge, and health activities, are played out. The outdoor water consumption for lawns and gardening (23 per cent of total household water demand) has increased in recent years by 50 per cent (New South Wales Government 2006). Most outdoor household water use relates to gardens, swimming pools, water features, spas, lawns, and washing of cars and pavements. The NSW Government's mandatory energy and water rating tool, the Building Sustainability Index (BASIX), aims to reduce water consumption by 40 per cent using sustainable technologies, such as rainwater tanks in new residences (New South Wales Government 2010). Swimming pools, unsealed ponds and impervious surfaces as features of Australian backyards are significant factors in sustainable water management. From environmental and ecological sustainability perspectives, 'unsealed ponds' could function as storm-water retention basins; reduce storm-water runoff volume; improve ground-water infiltration, and enhance biodiversity. On the other hand, swimming pools indicate imperviousness and higher use of water if not sourced from an alternative source, such as rainwater.

A clothesline, a very common feature in Australian suburban gardens, was found in 94 per cent of the

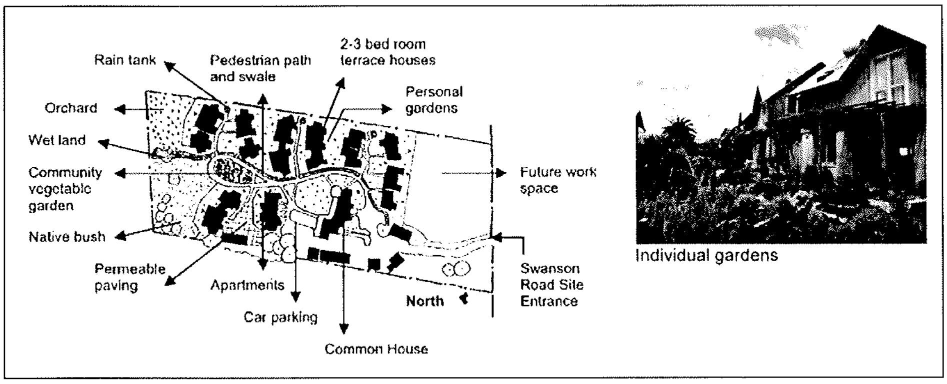

Figure 2 **Earthsong Eco-Neighbourhood, Waitakere City, New Zealand** (Drawing and photo by Sumita Ghosh; Information source: Earthsong Eco-Neighbourhood 2010)

sampled gardens in the 'Backyard' project (Head & Muir 2007a). It signifies use of a renewable solar energy resource for drying clothes and, thus, reduces associated domestic energy use and carbon dioxide emissions that would result from the use of clothes driers. In New South Wales, 78.1 per cent of households use a private outdoor clothesline (ABS 2006). Averaging the quantities of carbon dioxide emissions savings estimated in the 'traditional' and 'modern' case studies referred to earlier, a suburban household could save 87 to 240 kilograms annually just by using a clothesline (Ghosh & Head 2009). The cumulative benefit of such savings across millions of suburban households could make a significant reduction in total carbon dioxide emissions.

Vegetable patches in suburban home gardens generate an informal, alternative, environmentally sustainable food resource (Gaynor 2006). As potential sites of local food production, home gardens could lower the carbon footprint, improve public health, and promote better social cohesion (Winklerprins 2002; Ghosh et al. 2008). An Australian Bureau of Statistics survey in 1992 estimated that an average Australian backyard grew an average of 70.4 kg of vegetables per year (ABS 1992). The 'Backyard' study found that vegetables and herbs were grown in 52 per cent of the backyard gardens studied. However, only a handful of households attained self-sufficiency in vegetable production (Head & Muir 2007a).

As capacity to grow local food varies with climate, rainfall patterns, soil characteristics, and personal motivation to grow food, it is difficult to estimate the potential of this resource. In addition, the sustainability of growing local food has been questioned. As no accounting of the amount of energy consumption and carbon dioxide emissions involved in trips to purchase seeds, plants and fertilisers; the use of water; methods of local food production; quantity of resultant produce; and amount of labour involved in home gardens has been carried out, it is not possible to assess the actual sustainability impacts of local food production in home gardens.

Trees in gardens could contribute to carbon dioxide emissions reduction (using the natural process of photosynthesis), carbon storage as biomass, and other beneficial ecological functions (Nowak & Crane 2002; American Forests 2010). A CITYgreen (software developed by American Forests) analysis estimated that a 'traditional' suburban development case study with 23.5 per cent of the total site covered by mature trees could sequester up to 102 metric tonnes of carbon dioxide annually (Ghosh & Head 2009). Depending on size and functions, such gardens could contribute to urban biodiversity protection, as well as native forest and urban forest remnants regeneration (Doody et al. 2010). Larger tree canopy cover associated with larger residential gardens (Loram et al. 2008) could add to improved water and energy management and better amenity. In the new smaller subdivisions, the smaller gardens generally have much less tree cover. Unless the garden spaces are well connected and innovatively designed in medium and high-density environments, this could have adverse impacts on biodiversity and ecological sustainability of settlements.

On-site composting methods in gardens include two types of practices: closed compost bins and open compost heaps. In the UK, one-third of a sample of rear gardens contained on-site compost sites, and these gardens were larger in size (Loram et al. 2008); whereas in Australia, one-fifth of sampled gardens had such sites (Head & Muir 2007a). On-site composting of household organic waste reduces the amount of waste in landfill sites and consequent methane generation. Further, fertiliser produced from on-site composting could be utilised successfully in local food production sites.

This analysis indicates that gardens are important sites of water and energy conservation, local food production, on-site waste composting, agro-biodiversity (e.g. birds, animals and tree plantings), carbon sequestration and

Table 2 **Research on physical attributes and sustainability**

Authors	**Research studies**	**Outcomes**
Research focus: land cover, urban form and density		
Whitehand et al. 1999	Urban morphogenesis or incremental changes in houses and gardens	Hard surfacing of the front garden is one of the most common small-scale changes
Smith et al. 2005	Areas of vegetated land cover on residential parcels with associated domestic garden spaces in different residential densities (10, 20, 30 and 40 houses per hectare) using GIS Three different housing types were studied: detached (single); semi-detached (one adjoining) and terrace (two or more) dwellings in the city of Sheffield, UK	Domestic garden spaces vary in these housing typologies The total proportional garden areas increased with the house parcel sizes with the addition of front garden spaces; Garden sizes are important as larger gardens support a variety of land covers important to biodiversity Housing densities provide implications for sizes of domestic garden land cover
Pauleit et al. 2005	A study of 11 residential areas in Merseyside, UK, on modelling changes in land use and land cover considering three environmental parameters: surface temperature, run off of rainfall, and green space diversity	Urban consolidation by infill development - major cause of loss of biodiversity Green space dynamics importantly influence urban environmental quality Close link between green space provisions and residential environmental performance
Research focus: ecological functions and sustainability		
Whitford et al. 2001	Ecological indicators used in four urban areas of Merseyside, UK	Strong influence of ecological performance of green spaces, especially treed areas Gardens collectively can form extensive, interconnected green space tracts
Daniels & Kirkpatrick 2006	Comparison of ecological compositions and uses of front and back yards of 107 gardens in 10 suburbs in Hobart, Tasmania	Backyards function as important food production sites in Australian suburbia
Gaston et al. 2005	Ecological functions of associated features in domestic gardens at a city-scale	Ponds, trees, nest boxes for birds, compost heaps, homes of domestic cats have potential significance for biodiversity conservation Higher diversity of species in domestic gardens
Thompson et al. 2005	Composition and diversity of the soil seed banks of private domestic rear gardens	Gardens as disturbed habitats play important roles in biodiversity conservation and regeneration
Thompson et al. 2004	Lawns in the 'natural' and completely human created continuum	Lawn area was a major determinant of species richness Species-accumulation was very similar to those of semi-natural grasslands
Hope et al. 2003	Links human resource abundance or wealth and plant diversity in urban ecosystems	A functional relationship exists
Moroney & Jones 2006	Comparing biodiversity preservation in 24 smaller and larger lot subdivisions (low- to medium-densities) in Brisbane using aerial photographs	Larger constructed areas and less biodiversity and anthropocentric spaces in smaller lots Bird species richness and abundance significantly greater in large lots Demonstrates importance of incorporating biodiversity in suburban planning, policies and regulations
Research focus: environmental impacts and sustainability		
Loram et al. 2008	Environmental importance of domestic gardens in five urban areas of UK using spatial GIS	Garden size has significant influence on garden composition linking housing characteristics, parcel/subdivision sizes and the nature of surrounding landscapes Domestic gardens have ability to contribute significantly towards reducing environmental impacts
Perry & Nawaz 2008	Potential impacts of increasing imperviousness in suburban areas especially domestic gardens	75 per cent of the increase in imperviousness was due to paving of residential front gardens
Stone 2004	Porous paving use in retrofitting existing driveways	Porous paving could increase infiltration from zero to 80 per cent and thus reduce storm-water runoff volume
Hasse & Nuissl 2007	Surface sealing in urban developments	Surface sealing has critical impact on reduction in ground water recharge; increase in storm-water runoff volume; decline of storm-water runoff volume and drop in evapotranspiration

storage by tree canopy cover and native vegetation restoration (Gaston et al. 2005; Daniels & Kirkpatrick 2006). The value of garden contributions to sustainability is recognised through development of certification and rating systems, and fact sheets and booklets with gardening advice and information on training programmes (ASLA et al. 2009; Sustainable Gardening Australia 2010). The Sustainable Sites Initiative, for example, is a new rating system that provides advocacy on sustainable design, implementation and management, and assesses the sustainability of designed landscapes using a point-based method (ASLA et al. 2009). Some research studies highlighting the sustainability significance of physical attributes of gardens are presented in Table 2.

Connecting suburban form, sustainability and social processes

The focus on urban form, as seen in the examples above, can tend to make people invisible in urban development planning. Yet, it is the human interactions with the physical structures that ultimately determine their sustainability. Much more research focus could be productively applied to these behavioural aspects.

A particular application to questions of sustainability has been in the culture of water use. Status aspirations can drive high levels of water consumption (Askew & McGuirk 2004). On the other hand, households are developing a variety of habits of water conservation (Allon & Sofoulis 2006; Head & Muir 2007b). The emotions felt in watering little plants in gardens for survival in drought conditions have promoted positive behavioural changes towards water conservation in gardens (Askew & McGuirk 2004; Allon & Sofoulis 2006). Peoples' self reported knowledge, understanding and motivation are powerful factors towards efficient grey-water or rainwater use in gardens (Ryan et al. 2009).

Building on work by Shove (2003) and Kaika (2005) about the interaction between technologies and everyday behaviours, Head and Muir (2007b) argued that the garden is not a passive backdrop against which conservationist practices are played out. Rather, it is in the relationship between house and garden that people, see, understand and participate in the network of water storage and distribution. Thus, for example, people use informal water gathering practices, such as the 'bucket in the shower', to save water for use on the garden. To the extent that gardens are particularly valued, householders are prepared to use their own labour in contributing to the water resource. This helps explain why recent per capita water consumption in detached houses with gardens in Sydney is little different to that of apartment and unit dwellers (Troy et al. 2005), the latter being less aware of the resource and their participation in it.

Gardens as active local food production sites have always been functionally and culturally important. Growing food in personal gardens (although requiring significant time and labour) is seen as a positive connection to nature and an escape from everyday, busy life (Gaynor 2006; Kneafsey et al. 2008). In the material practices of gardening, the realities of production generate 'a more transparent relationship between food, produce and consumer' (Kneafsey et al. 2008, p. 131), thereby contributing to local sustainability knowledge.

The production of traditional fruits, vegetables, herbs and flowers in migrants' domestic gardens (e.g. Vietnamese, Greek and Italian migrants) in Australia reflects connections to cultural identities, memories, traditions and homeland practices (Graham & Connell 2006). Within a multicultural landscape, continuously negotiated hybrid and new identities are emerging in migrants' gardens through dynamic inter- and intra-generational social processes (Graham & Connell 2006; Head & Muir 2007a). Thus, domestic gardens provide a place for experiencing belonging, maintaining cultural continuity, retaining traditional and cultural practices, and generating new networks of social and biotic interactions.

A body of cultural geographic work on human–non-human interactions in domestic gardens provides illustrative examples (Power 2005; Head & Muir 2007a, 2007b). Power (2005) argued that gardens contribute to dynamic, complex engagement of human and non-human actors beyond simple cultural reflections. Like plants, animals can work with humans in shaping inclusive, negotiated and collaborative gardens (Power 2005).

Garden compositions reflect gardener types. The gardeners' attitudes towards aesthetics, biodiversity (birds and animals), and plant choices are translated in their gardens. Non-gardeners, as stylists, appreciate the aesthetics of backyards mainly as entertainment places. Garden makeovers are highly influenced by market forces and media advertisements (Head & Muir 2007a). With the changing nature of Australian suburbs, suburban garden spaces are decreasing. However, a new rhetoric of aesthetically valuing garden space has emerged (Johnson 2006). Gardens as designed, outdoor living spaces and their features now symbolise social status and purchasing power of residents (Davison 2006).

In these examples, peoples' engagement with plants, pets, birds and animals, and their behavioural patterns within the changing boundaries of suburban garden designs, provide important clues for reconstructing positive pathways to sustainability. Table 3 highlights some important research studies on social and cultural aspects of sustainability.

Synthesis

Key research trends and barriers

Suburban gardens are evolving through a dynamic process and are intrinsically linked to the community that lives within these places. Key sustainability research trends on suburban domestic gardens relate to:

- ecological functions and biodiversity values of gardens
- social and cultural engagements, and human and non-human interactions
- gardens as connective elements to natural landscapes
- morphological structure, spatial distributions and classification of gardens
- life-cycle changes in houses and gardens
- sustainability impacts of user behaviour, attitudes and practices
- contemporary garden designs and sustainability
- innovative applications of sustainable practices and technologies.

Suburban domestic gardens could provide multiple sustainability benefits. However, domestic gardens are generally considered to be small units of fragmented habitat and their potential contribution to sustainability has not been well documented or understood. Compounding this, research approaches to gardens from multi-disciplinary perspectives have not been well articulated. More emphasis will be needed to integrate quantitative with qualitative methods (e.g. mixed methods) in suburban sustainability research. A disconnection between research, policy and practice makes it difficult to achieve comprehensive goals and a future vision of ecologically-sound and environmentally-responsive built environments.

Current knowledge is able to provide sufficient guidance on how suburban garden spaces could practically accommodate important on-site practices and alternative

Table 3 **Examples of social research on suburban gardens**

Authors	Research areas	Outcomes
Research focus: cultures of water use		
Askew & McGuirk 2004	Examines importance of socio-cultural variables in water conservation	Accumulation of cultural capital through social distinction, and conformity of values and interpretation, influences typical water usage patterns and practices in human habitats
Allon & Sofoulis 2006	Investigates water consumption relating to changing every practices	Daily water practices of people are shaped by a combination of ideas and practices, which interact with technologies, and requires multi-dimensional strategies across cross-disciplinary fields
Head & Muir 2007b	Analyses peoples' understandings, participation and interventions in water use and conservation practices in network of storage and distribution in homes and gardens.	Active socio-technical engagement of people in the processes and practices of everyday household water use enhances households' capacities to consciously manage, to take responsibility for usage, and to adopt conservationist water practices to reduce consumption in constraint situations such as drought
Research focus: Growing local food		
Gaynor 2006	Explores a web of connections in food-producing suburbs of Australia	Highlights importance of sustainability, the multiplicity of human–environment relations, and economic, social and cultural contexts in growing food in Australian cities extending into history
Kneafsey et al. 2008	Evaluates alternative food choices and relationships in re-connecting producers, consumers and food systems in growing and selling food	Reconnection to alternative food system could foster recognition and better provisions of 'good food', social justice, better health, caring for the environment and sustained engagement between producers and consumers
Kortright 2007	Explores contributions of home food production to community food security	Local food growing in home gardens contributes to food security at all income levels, improves health and well-being; secures access to appropriate land; and lack of gardening skills were the most significant barriers to local food growing.
Research focus: migrant reflections and identities		
Head & Muir 2007a	Evaluates migrants' (Macedonian, Vietnamese and British-born) residential backyards' reproduction of memory, traditions and practices and their blending with Australian environments	A cultural shift is essential to adopt a sustainable life-style, and migrant gardens represent new pathways and networks through which humans negotiate their presence in new landscapes
Graham & Connell 2006	Examines first and second generation migrants' (Vietnamese and Greek); relationships between migrant history and garden-making practices, and compares their subsequent influences on gardens in Australian urban/suburban landscapes	Migrants' relationships with their Homeland influence garden composition. Gardens have been represented as nostalgic places for nurturing their passion for cultural continuity and sense of ownership and control
Research focus: human and non-human interactions		
Power 2005	Examines human–nature relations using actor–network theory framework	Gardens are complex, hybrid places for dynamic and active social interactive processes between human and non-human (e.g. plants and animals) actors
Research focus: gardener and garden types		
Head & Muir 2007a	Evaluates people's intentional relationships with plants and animals in generating different garden typologies and gardener types	Three types of gardeners: committed native; general native: non-native and non-gardeners are identified. People respond in diverse ways to nature which is reflected in their choice of plants and interest or lack of interest in gardening practices
Kortright 2007	Identifies garden types and gardeners from a specific user focus and purpose	Five garden types with varying qualities are identified: cook's garden; teaching garden; hobby garden; environmental garden; and aesthetics garden. It identifies how diverse ways of gardening could address issues of community food security from multiple perspectives
Research focus: social connections between urban and rural		
Winklerprins 2002	Explores rural-urban linkages of house-lot or home gardens in Brazil in fostering social connections through exchanges of garden products	Gardens link urban and rural environments through garden products exchanges, and maintain critical social networks. Gardens can be conceptualised as sites of agro-biodiversity, a source of food, and as transition zones between urban and rural environments with immense aesthetic and social values

designs to enhance urban sustainability. However, implementation gaps exist, as the suburban community is unaware of their gardens' significant potential to contribute to household shares of energy and water demands. More targeted policy-appropriate directives and regulatory legislation will be essential for implementing efficient garden practices. New renewable technologies need to be familiar to people, easily available, cheaper and subsidised for quick uptake. Community awareness, participation and positive behavioural changes towards sustainability in suburban gardens would play a significant role in demand reduction and biodiversity protection. In addition, achieving meaningful collaborative partnerships between local authorities, power companies, federal departments, research institutions, community and other stakeholders will be necessary and highly valuable in enhancing sustainability performance of domestic gardens.

Current research on sustainability performance of suburban gardens is in a formative stage but there is substantial potential to enhance understanding and implementation of urban sustainability values. Future sustainability research and policy should explore and address these values and their inter-connections in an integrated manner.

Conceptual sustainability model for suburban gardens

Drawing on the research review and analysis, a conceptual sustainability map for suburban gardens is formulated at a neighbourhood or local spatial scale. Three basic factors are: design and form, potential and technologies, and social processes (Figure 4).

The sustainability attributes of suburban gardens can be holistically represented and could be connected. The four form-specific attributes: morphological urban and suburban structure; land cover; design elements; and spatial typology embedded in the suburban form could impact significantly on sustainability performance. Seven core social sustainability qualities reflected in the sustainability of gardens are: culture, practices, belonging, participation, awareness and behaviour. Five biophysical fields for generating sustainability potential are: water, energy, local food, carbon, waste and biodiversity.

This sustainability model provides a realistic cross-disciplinary base for assessing integrated sustainability performance of suburban gardens. It acknowledges the importance of collective social, cultural, environmental and ecological initiatives for improved sustainability performance.

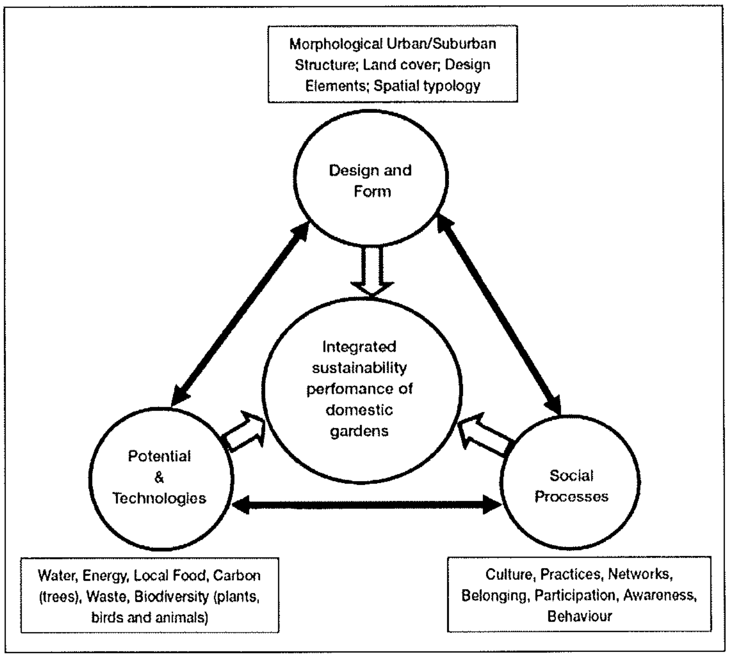

Figure 4 **A conceptual sustainability model for domestic gardens**

Conclusion

This article reviews the sustainability potential of domestic gardens and their links to suburban morphologies, design, social processes, and environmental and ecological sustainability functions. It establishes that domestic gardens are immensely important elements of suburban neighbourhoods and can provide multiple sustainability benefits. The holistic conceptual sustainability model provides a foundation for formulating an integrated model for future sustainability assessment of domestic gardens. Human settlements in urban, suburban and rural areas will not change dramatically within a short timeframe. Therefore, it is essential to understand the role and performance of the suburban garden in this discourse. Sustainability of suburban residential environments essentially warrants immediate and close attention from government, local and regional authorities, and developers, concurrently and with concerted efforts to develop sustainable cities in Australia.

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